Effect of eHealth-delivered exercise programmes on balance in people aged 65 years and over living in the community: a systematic review and meta-analysis of randomised controlled trials

Meghan Ambrens, Stephanie Alley, Juliana S Oliveira, Quyen To, Kim Delbaere, Corneel Vandelanotte, Anne Tiedemann

ABSTRACT

Introduction Exercise that challenges balance is proven to prevent falls in community-dwelling older people, yet widespread implementation and uptake of effective programmes is low. This systematic review and meta-analysis synthesised the evidence and evaluated the effect of eHealth-delivered exercise programmes compared with control on balance in community-dwelling people aged ≥65 years.

Methods Nine databases including MEDLINE, CINAHL and Embase, were searched from inception to January 2022 to identify randomised controlled trials evaluating eHealth-delivered exercise programmes for community-dwelling people aged ≥65 years, published in English that included a balance outcome. Primary outcomes were static and dynamic balance. Secondary outcomes included fall risk and fear of falling. We calculated standardised mean differences (SMDs, Hedges’ g) with 95% CIs from random effects meta-analyses.

Results We identified 14 eligible studies that included 1180 participants. Methodological quality ranged from 3 to 8 (mean, 5). The pooled effect indicated that eHealth-delivered exercise programmes have a medium significant effect on static balance (11 studies; SMD=0.62, 95% CI 0.27 to 0.72) with very low-quality evidence. There was small statistically significant effect on dynamic balance (14 studies; SMD=0.42, 95% CI 0.11 to 0.73) with very low-quality evidence, and fall risk (5 studies; SMD=0.32, 95% CI 0.00 to 0.64) with moderate-quality evidence. No significant effect of eHealth programmes on fear of falling was found (four studies; SMD=0.10, 95% CI −0.05 to 0.24; high-quality evidence).

Conclusion This review provides preliminary evidence that eHealth-delivered exercise programmes improved balance and reduced fall risk in people aged ≥65 years. There is still uncertainty regarding the effect of eHealth delivered exercise programmes on fear of falling.

STRENGTHS AND LIMITATIONS OF THIS STUDY

We conducted this systematic review in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines and followed a prespecified protocol registered on PROSPERO.

We had specific criteria that allowed for the inclusion of studies with both generally healthy participants and those with selected clinical conditions.

We also ensured the inclusion of as many relevant studies as possible by searching across nine databases, conducting a thorough hand search of relevant published literature and consulting with experts in the field.

Included studies had to comprise a measure of balance and we may have missed relevant studies that included measures of falls.

We only included outcome data from the immediate postintervention time point, which limits the interpretation of results to the short-term.

INTRODUCTION

Ageing is associated with a decline in the physiological systems responsible for postural stability and hence an increase in the risk of falls. A fall is defined as ‘an unexpected event in which the participants come to rest on the ground, floor, or other lower level’. Each year approximately one-third of community-dwelling people aged 65 years and over experience a fall. Forty per cent of injuries requiring hospital admission are due to falls, and in 2016–2017 more than 125,000 Australians aged 65 years or over were hospitalised due to a fall. Falls place a significant burden on health systems and can result in serious long-term costs to the individual. Falls can also result in the loss of independence, depression, social isolation and admission of
The systematic review protocol has been published and provides a full outline of the methods. A summary of the methods is reported in this paper.

**Data sources**

A database search was conducted from inception to January 2022 of MEDLINE, CINAHL Complete, Embase, PsychINFO, Scopus, Web of Science, PubMed Central, Cochrane Database Central and PEDro. The protocol details the complete search strategy used. Online supplemental figure 1 provides the MEDLINE search strategy.

**Eligibility criteria**

Studies included in this systematic review met the following criteria: (1) published in English, (2) randomised controlled trials (RCTs), (3) participants were community-dwelling people aged ≥65 years, (4) reported data for a validated measure of balance, (5) included eHealth delivery of an exercise programme compared with no intervention, usual care or wait-list control. Studies that did not meet these criteria were excluded.

We included all RCT designs such as crossover, cluster, patient-randomised clinical trials that examined the effect of eHealth-delivered exercise programmes vs a control group. Single and multi-factorial interventions were also included. Studies published only as abstracts or yet to be published were excluded due to possible data inaccuracy and incompleteness.

**Outcome measures**

The primary outcome measure was balance, defined as staying upright and steady when stationary, such as when standing, or sitting, or during movement. Technically, balance is defined as ‘the ability to maintain the projection of the body’s centre of mass (CoM) within manageable limits of the base of support, as in sitting or standing, or in transit to a new base of support, as in walking’. The balance outcomes were further categorised as static or dynamic measures of balance in the analyses. Static balance refers to maintaining balance when the body has a constant or static base of support. Whereas dynamic balance refers to maintaining balance during movement from one base of support to another, such as when walking. In the absence of functional measures of balance, we included studies which reported direct measures of balance, such as those measured with a force platform. Fall risk, fear of falling and fall rate were included as secondary outcomes. We included studies that used either validated self-report questionnaires or performance-based measures for these outcomes.

**Study selection**

After pilot-testing criteria for full-text articles, screening for eligible studies was conducted independently by two reviewers (MA, KLA/RS). An electronic screening form was used, and screening occurred in stages: first, titles were screened, followed by abstracts and finally...
full-text articles were screened. Conflicts were resolved by consensus from AT, KD and CV.

Data extraction
Data extraction was completed by two researchers independently from one another (MA, QT), and conflicts were resolved by a third reviewer (SA). Data were extracted using a piloted electronic data extraction form, and according to the PRISMA statement. Where data were missing, study authors were contacted by email to provide further information. Where the authors did not reply within 2 weeks, a second email was sent as a reminder.

The following data were extracted from each study: author, year of publication, country, sample characteristics (sample size, age, sex of participants and health status), study design: including number of study arms, recruitment sources, eligibility criteria, setting, delivery method and technology used, intervention description, comparator, intervention duration and frequency, assessment time-points. Also extracted were data on drop out, attrition, adverse events and intervention features such as implementation fidelity, evidenced-based theory, tailoring, supervision, intervention acceptability. Primary and secondary outcome data were extracted for preintervention and postintervention timepoints. Where data were available for more than one postintervention timepoint, we included the data from the timepoint closest to intervention completion.

Methodological quality and risk of bias assessment
The PEDro scale (1–10) was used to assess the methodological quality of the included studies. PEDro scores were extracted from the PEDro database. The PEDro scale assesses the internal validity of an RCT by evaluating 11 items: participant eligibility criteria, random allocation, concealed allocation, homogeneity of groups at baseline, blindness of subjects, blindness of therapist, blindness of assessor, completeness of follow-up, intention-to-treat analysis, between-group statistical analysis, and variability and point measures. A score of 10 is considered to be methodologically excellent, whereas 0 demonstrates poor methodological quality. Methodological quality was not an inclusion criterion for this review.

In addition to the PEDro scale, we also used the Cochrane Risk of Bias to assess the risk of bias in each included study. The Cochrane Risk of Bias was undertaken by two independent reviewers (MA, SA) with conflicts resolved by a third reviewer (CV). Risk of bias is assessed across a number of domains as a judgement of low risk, high risk, or unclear.

Assessment of quality of evidence
To evaluate overall quality of evidence we used the Grading of Recommendations, Assessment, Development and Evaluations (GRADE) system. The GRADE appraisal was conducted by pairs of independent reviewers (MA, JSO) and guided by the Cochrane Handbook for Systematic Reviews. This is a subjective evaluation of the quality of the evidence as high, moderate, low or very low based on the presence or extent of the following factors: risk of bias, imprecision and inconsistency of the effect. The GRADE classification was downgraded from high quality by one level for each factor encountered: (1) design limitations (>25% of studies with low methodological quality based on the Cochrane Risk of bias), (2) inconsistency of results (large heterogeneity between the studies I²>50%), (3) imprecision (<400 participants for each outcome). We did not consider indirectness as it encompasses a specific population (older people) with relevant outcome measures (balance) and direct comparisons. We were unable to consider publication bias for secondary outcome measures due to the limited number of studies that collected measures for the fall-related outcome measures.

Statistical analysis
We performed meta-analyses with Comprehensive Meta-Analysis software (V.3, Biostat, Englewood, New Jersey, USA) using the random effects models for primary and secondary outcome measures. The random effects model was chosen given the heterogeneity of the population and the interventions being evaluated. We calculated treatment effects for the continuous variables using standardised mean differences (SMDs, Hedges’ g) standardised by postscore standard deviation (or its estimate) with 95% CIs, for either between-group differences in point estimates at the follow-up time points or between-group differences in change scores based on available data. SMDs were calculated using the premean and postmean and SD. Where this was not available, we used the mean change score. Effect sizes were categorised as small (0.2), medium (0.5) or large (0.8 or greater).

We visually inspected the forest plot for evidence of heterogeneity among studies with consideration of the I² and χ² tests. We determined clinical heterogeneity by consensus among the investigators on the basis of collective experience in the field.

RESULTS
Flow of studies included in this review
The initial search of the databases resulted in 1080 publications. An additional hand search, including the reference lists of relevant review articles found a further 40 publications. After removing duplicate papers, 783 publications were screened by title and abstract. Forty-five publications reported on potentially eligible studies before full-text screening. After the full-text screen, 14 studies, reported by 15 manuscripts, were identified as eligible and included in this study. Schoene et al conducted a study involving interactive cognitive-motor step training, however this paper did not report the balance outcomes measured during this study. These balance outcomes were reported in Gschwind et al as the step-mat-training (SMT) intervention group. This review extracted outcome data for the SMT group only from
Open access

Records identified through search of MEDLINE, EMBASE, PsycINFO, databases
CINAHL, Complete, Scopus, Web of Science, PubMed Central, Cochrane Database Central, and PEDro (n=1086)
Records identified through handsearching relevant review articles reference list (n=40)

Screening of title & abstracts (n=783)
Excluded after screening of title and abstract (n=738)
Studies included in the review (n=14)
Studies included in the meta-analysis (n=14)

Figure 1 Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow of studies through the review.

RCT, randomised controlled trial.

Gschwind et al66 paper, all other data pertaining to this study (including for the control group) were extracted from Schoene et al35 Figure 1 outlines the PRISMA study flow of studies included in this review.

We pooled all included studies in the primary meta-analysis evaluating the effect of interventions that use an eHealth technology to deliver an exercise programme to older people.

Risk of bias and quality

Table 1 reports the methodological quality of eligible studies. The total PEDro scores ranged from 3 to 8 (mean of 5). For the static balance outcome five studies out of 11 (45%) were of high methodological quality (a score ≥6).18 36–39 For the dynamic balance outcome, 5 studies out of 14 (36%) were of high methodological quality.18 36–39 All participants were randomly allocated and provided the calculation of point estimates and variability (PEDro items 2 and 11). Four studies out of 14 (29%) did not undertake an intention-to-treat analysis18 40–42 and 3 studies provided insufficient information to determine this.43–45 None of the studies included blinded participants or blinded therapists, however, blinding of participants or therapists is not possible for exercise interventions. Figure 2 presents the risk of bias.

Cohort characteristics

Studies included samples ranging from 9 to 503 participants (n=1180). The mean age of participants ranged from 65 to 89 years. Both males and females were included in 11 studies, all had a higher percentage of female participants.18 36–38 40 42 46 47 Two studies included only female participants,11 45 one study included only male participants.68 Every study recruited participants from the general community.18 36–48 Two studies recruited participants with a history of falls.41 45 Table 1 presents a summary of cohort characteristics.

Characteristics of included studies

Publication dates ranged from 2013 to 2021, with 11 (76%) published during or after 2015. Studies were conducted in eight different countries: single studies were conducted in Hong Kong,46 Taiwan,47 the USA,42 the UK,40 Japan,44 Malaysia48 and Thailand;36 three studies were conducted in Australia18 36 39 and South Korea,37 41 45, and one study was conducted across three countries: Germany, Spain and Australia.38 Details of study characteristics are summarised in table 1.

eHealth-delivered exercise programmes

The duration of the included interventions ranged from 2 to 52 weeks, with a mean duration of 12 weeks. Eleven studies (79%) used a commercially available exergame system to deliver the exercises: five (36%) used the Microsoft Xbox Kinect,38 43 44 46 48 four (29%) studies used the Nintendo Wii console,37 40 42 45 two (14%) used the Dance Dance Revolution StepMania.18 36 Three studies (21%) used customised technologies: an app-based intervention called StandingTall,39 a web-based intervention called telepresence,41 and the Xavix Measured Step System.47

Five studies (36%) used technology to provide a home-based intervention.18 36 39 41 Nine studies (64%) used technology to deliver a supervised intervention: participants attended a supervised group class,37 44 46 or a supervised one-on-one session.40 42 43 45 47 48

In seven studies (50%), the control group received no information and were encouraged to continue with normal daily activities.40 42 47 Control participants in five studies (36%) received educational advice related to fall prevention, general health, nutrition and physical activity, in the form of a booklet or classes.36–39 41 Participants in one study continued with the regular, seated social games available at the senior’s activities centre.46

Effect of eHealth-delivered exercise programmes on balance

Eleven studies (79%) measured static balance using static balance,39 single leg stance,37 46–48 tandem stance,48 postural sway,18 36 40 functional reach,45 and the Fullerton Advanced Balance Scale.42 The pooled effect of eHealth-delivered exercise programmes on static balance indicates a medium, statistically significant effect compared with control (SMD=0.62, 95% CI 0.27 to 0.72; I²=82%, p=0.001) (figure 3). The pooled results provide very low-quality evidence (GRADE).

All 14 studies measured dynamic balance with methods ranging from the Timed Up and Go,36–39 42 43 45–48 the Berg Balance Scale,40 41 44 and the Alternative Step test.18 The pooled effect of eHealth-delivered exercise programmes on dynamic balance indicates there was a small, statistically significant effect compared with control (SMD=0.42, 95% CI 0.11 to 0.73; I²=79%, p=0.009) (figure 4). The pooled results provide very low-quality evidence.
Table 1 Summary of the characteristics of the included studies

<table>
<thead>
<tr>
<th>Study author; country</th>
<th>Study design; sample size; PEDro score</th>
<th>Mean age; % female; health status</th>
<th>Intervention content</th>
<th>Outcome measures: primary and secondary</th>
<th>Tailored progression of exercises</th>
<th>Dosage: duration; session length; frequency</th>
<th>Setting</th>
<th>Comparator</th>
<th>Adverse events</th>
<th>Intervention acceptability and how it was assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bieryla and Dold; USA</td>
<td>RCT; N=12; 3</td>
<td>81.5±5.5; 83%; healthy</td>
<td>Exercises: yoga (half-moon, chair, warrior), aerobic (torso twist), balance games (soccer heading, ski jump)</td>
<td>Primary: FAB, BBS</td>
<td>3 wk; 30 min; 3 x wk</td>
<td>Centre; supervised</td>
<td></td>
<td></td>
<td></td>
<td>Not assessed</td>
</tr>
<tr>
<td>Chow and Mann; Hong Kong</td>
<td>RCT; N=20; 3</td>
<td>70.4; 65%; healthy</td>
<td>Exercises: Tiger Woods PGA Tour 13 golf game</td>
<td>Primary: SLS, TUG</td>
<td>2 wk; 30–45 min; daily</td>
<td>Centre; supervised</td>
<td></td>
<td></td>
<td></td>
<td>Not assessed</td>
</tr>
<tr>
<td>Delbaere et al; Australia</td>
<td>RCT; N=503; 8</td>
<td>77.1±5.5; 67%; healthy</td>
<td>Exercises: balance and lower limb muscle strength; health education</td>
<td>Primary: standing balance, TUG Secondary: PPA, icon-FES</td>
<td>↑ intensity; ↑ challenge ↑ duration</td>
<td>52 wk (balance measures), 104 wk (fall measures); 120 min per wk</td>
<td>Home; unsupervised</td>
<td>Health education programme delivered via iPad</td>
<td>5 falls</td>
<td>SUS to assess usability</td>
</tr>
<tr>
<td>Gschwind et al; Australia, Germany, Spain</td>
<td>RCT; N=153; 6</td>
<td>74.7±6.3; 61%; healthy</td>
<td>Exercise: balance and muscle strength; educational booklet on general health and fall prevention</td>
<td>Primary: tandem stance, TUG Secondary: icon-FES, PPA</td>
<td>16 wk; balance: 40 min; 3 x wk. Strength: 15–20 min; 3 x wk</td>
<td>Home; unsupervised</td>
<td>Educational booklet: general health and fall prevention</td>
<td>24 falls (IG: 8, CG: 15)</td>
<td>SUS to assess usability and enjoyment; DART to assess user acceptance.</td>
<td></td>
</tr>
<tr>
<td>Gschwind et al; Schoene et al; Australia</td>
<td>RCT; n=90; 7</td>
<td>82±7; 66%; healthy</td>
<td>Exercises: trail-stepping — visual attention, set-shifting; stepping to connect numbers and letters, Tetris-stepping — visuo-spatial skills, problem-solving; stepping</td>
<td>Primary: standing balance, TUG Secondary: icon-FES, PPA</td>
<td>↑ intensity; ↑ challenge</td>
<td>16 wk; 20 min; 3 x wk</td>
<td>Home; unsupervised</td>
<td>Educational booklet: general health and fall prevention</td>
<td>Not assessed</td>
<td></td>
</tr>
<tr>
<td>Hong et al; South Korea</td>
<td>RCT; N=30; 5</td>
<td>78.10; 100%; fall risk</td>
<td>Exercises: resistance, two-legged standing, tandem standing, one-legged standing, semi-tandem standing, tandem walking, turning in a circle, toe stands-nutrition and exercise education</td>
<td>Primary: BBS Secondary: FES-K</td>
<td>↑ intensity</td>
<td>12 wk; 20–40 min; 3 x wk</td>
<td>Home; supervised</td>
<td>Nutrition and exercise education</td>
<td>Not assessed</td>
<td></td>
</tr>
<tr>
<td>Jung et al; Republic of Korea</td>
<td>RCT; N=24; 4</td>
<td>74.3±2.1; 100%; fall risk</td>
<td>Exercises (NWS group); including the wakeboard, Frisbee dog, jet ski and canoe games</td>
<td>Primary: functional reach, TUG, BBS</td>
<td>8 wk; 30 min; 2 x wk</td>
<td>Centre; supervised</td>
<td></td>
<td></td>
<td></td>
<td>Not assessed</td>
</tr>
<tr>
<td>Lai et al; Taiwan</td>
<td>Cross-over; N=30; 4</td>
<td>70.6±3.5; 57%; healthy</td>
<td>Exercises: IVGB stepping exercise</td>
<td>Primary: SLS, BBS</td>
<td>6 wk; 30 min; 3 x wk</td>
<td>Centre; supervised</td>
<td>Cross-over trial</td>
<td>Not assessed</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Continued
<table>
<thead>
<tr>
<th>Study author; country</th>
<th>Study design; sample size; PEDro score</th>
<th>Mean age; % female; health status</th>
<th>Intervention content</th>
<th>Outcome measures: primary and secondary</th>
<th>Tailored progression of exercises</th>
<th>Dosage: duration; session length; frequency</th>
<th>Setting</th>
<th>Comparator</th>
<th>Adverse events</th>
<th>Intervention acceptability and how it was assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lee et al; South Korea</td>
<td>RCT; N=44; 6</td>
<td>76.15±4.55; 77%; healthy</td>
<td>Exercises: jogging for gait, swordplay for agility and balance, ski jump for balance, hula-hoop for balance and lower extremity strength, tennis for balance and agility, and step dance for gait for lower extremity strength</td>
<td>Primary: SLS, BBS</td>
<td>6 wk; 60 min; 2 x wk</td>
<td>Centre; supervised</td>
<td>3x fall education sessions</td>
<td>Not assessed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phirom et al; Thailand</td>
<td>RCT; N=40</td>
<td>70.21±4.18; healthy</td>
<td>Exercises: interactive game-based training which involved stepping on different targets and in different directions and balance training</td>
<td>Primary: TUG Secondary: PPA</td>
<td>12 wk; 60 min; 3 x wk</td>
<td>Centre; supervised</td>
<td>Not assessed</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sadeghi et al; Malaysia</td>
<td>RCT; N=64; 5</td>
<td>71.8±6.09; 0%; healthy</td>
<td>Exercises (BT group): single-leg stance with eyes open and closed, standing on heels or toes, tandem and semi-tandem foot stance, tandem walking, walking backward and forward, and weight shifting</td>
<td>Primary: SLS, TUG ↑ intensity ↑ challenge</td>
<td>8 wk; 40 min; 3 x wk</td>
<td>Centre; supervised</td>
<td>Educational material covering cognitive enhancement and fall prevention strategies</td>
<td>Not assessed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sato et al; Japan</td>
<td>RCT; N=54; 4</td>
<td>69.25±5.41; 80%; healthy</td>
<td>Complete four games—apple game, balloon popping game, tightrope game, one-leg standing game</td>
<td>Primary: BBS</td>
<td>9 wk (24 sessions); 40-60 min; 2–3 x wk</td>
<td>Centre; supervised</td>
<td>Not assessed</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Schoene et al; Australia</td>
<td>RCT; N=37; 7</td>
<td>77.5±4.5; healthy</td>
<td>Exercises: a series of stepping challenges+cognitive load</td>
<td>Primary: SB, AST Secondary: icon-FES, PPA ↑ intensity</td>
<td>8 wk; 15–20 min; 2–3 x wk</td>
<td>Home; unsupervised</td>
<td>Participants were asked whether they enjoyed playing the exergame (YES/NO response)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Whyatt et al; UK</td>
<td>RCT; N=82; 5</td>
<td>77.18±6.59; 70%; healthy</td>
<td>Exercises: games targeting components of balance (Apple Catch, Bubble Pop, Avoid the Shark, Smart Shrimp)</td>
<td>Primary: SLS, TUG Secondary: ABC Scale ↑ challenge</td>
<td>5 wk; 30 min; 2 x wk</td>
<td>Centre; supervised</td>
<td>Activity diaries</td>
<td>Not assessed</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Wk: week(s); PEDro: Physiotherapy Evidence Database (used to rate the methodological quality of studies—‘poor’ PEDro score of 1–3, ‘moderate’ PEDro score of 4–5 and ‘high’ PEDro score of 6–10); IVGB: interactive video game based; +, plus; ↑, increase; Centre: exercise delivered within a gymnasium, clinic or other facility that is not the participants place of residence; Primary: primary outcome measure, Secondary: secondary outcome measure; Static balance: SLS, Single Leg Stand; SB, Standing Balance; FAB, Fullerton Advanced Balance Scale; Dynamic balance: BBS, Berg Balance Scale; TUG, Timed Up and Go; FR, functional reach; AST, Alternative Step Test; Fear of Falling; Icon-FES, Iconographical Falls Efficacy Scale; FES-K, Falls Efficacy Scale Korea; FES-I, Falls Efficacy Scale-International; Fall risk: PPA, Physiological Profile Assessment; IG, intervention group; CG: control group; NWS group: Nintendo Wii Sports group; NSW BT group: balance training group; SUS: System Usability Scale; DART: Dynamic Acceptable Model for the Re-evaluation of Technologies.
(GRADE). Online supplemental figure 2 provides the Funnel plot for static and dynamic balance.

**Effect of eHealth-delivered exercise programmes on secondary outcomes**

Five studies (36%) measured fall risk using the Physiological Profile Assessment. The pooled effect of eHealth-delivered exercise programmes on fall risk indicates a small effect compared with control (SMD=0.32, 95% CI 0.00 to 0.64; I²=69.6%, p=0.048). The pooled results provide moderate-quality evidence (GRADE).

Four studies (29%) reported measures of fear of falling using the shortened Iconographical Falls Efficacy Scale, or the Fear of Falling Questionnaire. The pooled effect indicates no significant effect of eHealth-delivered exercise programmes on fear of falling compared with control (SMD=0.10, 95% CI −0.05 to 0.24; I²=0.0%, p=0.201). The pooled results provide high-quality evidence (GRADE).

Two studies collected data for fall rate. However, Lee et al only reported a baseline measure for fall rate without providing further follow-up data. We were therefore unable to report on fall rate.

**Adverse events**

Eight included studies (57%) measured adverse events. Of those reported, no major adverse events were related to the intervention.

**DISCUSSION**

This systematic review and meta-analysis provides preliminary evidence that eHealth-delivered exercise programmes improve balance (static and dynamic) and provide an alternative method of delivering an exercise programme to people aged 65 years or over living in the community. This reviews also demonstrates that an eHealth-delivered exercise programme may improve fall risk in people aged 65 years or over living in the community. However, we are uncertain whether an eHealth-delivered exercise programme improves fear of falling or fall rate in people aged 65 years or over living in the community.

There are a number of factors that may have influenced these results. First, the dose and intensity of the prescribed exercise in many of the studies may have been insufficient to substantially improve dynamic balance. A Cochrane review examining the effects of exercise interventions on balance found effective programmes were those attended three times per week for 3 months and involved dynamic exercises in a standing position.

While in 79% of studies (11/14) participants completed intervention exercises three times per week, only five studies had an exercise duration of 12 or more weeks. Furthermore, a systematic review on falls prevention programme to people aged 65 years or over living in the community.
found greater effects from interventions that challenged balance and included ≥3 hours per week. Six studies (43%) included tailoring (increases in intensity and challenge). In addition, only four studies engaged participants in at least 180 min of exercise per week for the duration of the intervention. Most studies (71%) only engaged participants for between 30 and 120 min of exercise per week. This suggests that the challenge to balance may not have been of a sufficiently high dose. Therefore, our results, which indicate a small but statistically significant effect on dynamic balance, are promising. Further research is needed to explore the effect of higher dosage (i.e., tailoring exercises to achieve increased intensity and challenge over the duration of the intervention) has on dynamic balance.

Finally, the tools used to measure dynamic balance may not be the most appropriate for the healthy older people. The most frequently used measure of dynamic balance was the Timed-Up-and-Go (TUG) (10/14). While the TUG is a validated tool and is recommended by the National Institute of Clinical Evidence for the assessment of gait and balance in the prevention of falls in older people, research has found the TUG may be more appropriate for frail older people who use walking aids rather than healthy older people.

The results for the secondary measures related to falls are mixed. While there was a small but significant effect on fall risk compared with the control, there is still uncertainty around the effect eHealth-delivered exercise programmes have on fear of falling. This is despite strong evidence that exercise interventions reduce falls in older community-dwellers. There are two possible explanations for these findings. First, to be eligible the included studies had to report on balance, resulting in only a small number (n=5 fall risk; n=4 fear of falling) of studies also reporting a fall-related measure. This suggests we may have missed studies that measured the other fall-related outcomes of interest. Second, it is likely that the studies that reported a fall-related outcome, were not powered to detect an impact on falls (sample sizes ranged from 30 to 503 participants).

**Implications for clinicians and policymakers**

Given the often low levels of adherence to exercise-based fall prevention programmes among older people, new delivery methods that improve access and encourage uptake of programmes designed to improve balance and reduce falls are needed. This review demonstrates that eHealth platforms are an effective mode of delivering exercises to improve balance. Although we identified an intervention effect on balance (static and dynamic), not only does this need to be considered in the context of the quality of the evidence but also in the ability to scale up and implement such interventions to large populations where resources are available. Clinicians should consider the use of eHealth platforms for delivering exercise programmes to older people living in the community.

**Unanswered questions**

Our results identified evidence of the benefit of eHealth-delivered exercise programmes on balance (static and dynamic) in older people living in the community. However, what remains unclear is the effect of eHealth-delivered exercise programmes on fall risk, fear of falling and fall rate in this population. Future research should focus on high-quality studies that deliver the recommended intensity and duration of exercise to provide a sufficiently high challenge to balance and impact on fall-related outcomes in a safe manner. Furthermore, future research needs to explore the long-term impact, cost-effectiveness and sustainability of eHealth-delivered programmes on balance and fall-related outcomes in older people living in the community.

**Author affiliations**

1. School of Health, Medical and Applied Sciences, CQUniversity, Rockhampton, Queensland, Australia
2. Neuroscience Research Australia, Randwick, New South Wales, Australia
3. Physical Activity Research Group, Appleton Institute, CQUniversity, Rockhampton, Queensland, Australia
4. Institute for Musculoskeletal Health, The University of Sydney and Sydney Local Health District, Camperdown, New South Wales, Australia
5. School of Public Health, Faculty of Medicine & Health, The University of Sydney, Sydney, New South Wales, Australia
6. School of Public Health & Community Medicine, University of New South Wales, Sydney, New South Wales, Australia

**Twitter** Meghan Ambrens @meghan_ambrens and Corneel Vandelanotte @corneelvd

**Acknowledgements** We acknowledge the assistance of Kristie-Lee Alfrey (KLA) and Rachael Smallwood (RS) for helping to screen the articles.

**Contributors** MA, CV, AT, SA and KD were involved in the conception of the design of this systematic review, including the scope of the review; development of selection criteria; and development of the data analysis strategy. MA and QT were involved in the screening and data extraction. MA and JSO were involved with
the GRADE. MA, JSO and AT were involved in the data analysis. MA drafted the manuscript. MA, CV, AT, SA and KD were involved in all revisions and edits made to the manuscript. MA, CV, AT, SA, KD, QT and JSO were involved in the final approval of the version to be published. We acknowledge the assistance of KLA and RS for the screening of articles. MA and AT acted as guarantor.

Funding The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval Not applicable.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement All data relevant to the study are included in the article or uploaded as supplementary information. We agree to share any additionally relevant data that has not been included in the article or uploaded as supplementary information.

Supplemental material This content has been supplied by the author(s). It has not been vetted by BMJ Publishing Group Limited (BMJ) and may not have been peer-reviewed. Any opinions or recommendations discussed are solely those of the author(s) and are not endorsed by BMJ. BMJ disclaims all liability and responsibility arising from any reliance placed on the content. Where the content includes any translated material, BMJ does not warrant the accuracy and reliability of the translations (including but not limited to local regulations, clinical guidelines, terminology, drug names and drug dosages), and is not responsible for any error and/or omissions arising from translation and adaptation or otherwise.

Open access This is an open access article distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is not commissioned; externally peer reviewed.

REFERENCES


Supplementary Figure 1: A draft literature search for MEDLINE (the key words search string)

<table>
<thead>
<tr>
<th>MEDLINE Search Strategy</th>
<th>Population</th>
<th>Intervention</th>
<th>Setting</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population</td>
<td>(senior* OR elderly OR aged OR old OR age OR &quot;older adult&quot; OR older OR 65 years)</td>
<td>(technology OR telemedicine OR telehealth OR &quot;communication technology&quot; OR ICT OR &quot;electronic health&quot; OR eHealth OR internet OR online OR tablet OR ipad OR web OR &quot;world wide web&quot; OR email OR website OR &quot;web-based&quot; OR &quot;website delivered&quot; OR PDA OR &quot;mobile health&quot; OR mHealth OR &quot;mobile phone&quot; OR &quot;short messaging service&quot; OR &quot;multimedia messaging service&quot; OR SMS OR &quot;multimedia messaging service&quot; OR MMS OR &quot;text message&quot; OR app OR smartphone OR &quot;cell phone&quot; OR &quot;cellular phone&quot; OR &quot;picture message&quot; OR tracker OR wearable* OR &quot;digital health&quot; OR &quot;Information technology&quot; OR fitbit OR garmin OR jawbone OR fuelband OR pedometer OR &quot;step counter&quot; OR sensors OR exergame* OR nintento OR wiifit OR wii-fit OR wii fit)</td>
<td>(community dwelling OR community-dwelling OR community dweller* OR community-dweller*)</td>
<td>(accidental falls OR falls OR faller OR fall* OR tripping OR balance OR mobility)</td>
</tr>
</tbody>
</table>
Supplementary Figure 2 Funnel plot of standard error by Hedges’ g for trial included in the meta-analysis for balance, fear of falling and fall risk. Each circle represents one trial.

a) Static balance

b) Dynamic balance